IS 7304-1 (1978): Code for Fabrication, Installation and Testing of Salt Water Piping System for Shipboard Use, Part I: General Requirements [TED 17: Shipbuilding]

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(Reaffirmed 2002)

Indian Standard

CODE FOR FABRICATION, INSTALLATION AND TESTING OF SALT WATER PIPING SYSTEM FOR SHIPBOARD USE

PART I GENERAL REQUIREMENTS

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CODE FOR FABRICATION, INSTALLATION AND TESTING OF SALT WATER PIPING SYSTEM FOR SHIPBOARD USE

PART I GENERAL REQUIREMENTS

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Indian Standard

CODE FOR FABRICATION, INSTALLATION AND TESTING OF SALT WATER PIPING SYSTEM FOR SHIPBOARD USE

PART I GENERAL REQUIREMENTS

0. FOREWORD

0.1 This Indian Standard (Part I) was adopted by the Indian Standards Institution on 31 July 1978, after the draft finalized by the Shipbuilding Sectional Committee had been approved by the Marine, Cargo Movement and Packaging Division Council.

0.2 This standard has been prepared to specify recommendations and requirements for salt water piping system in ships with the object of improving their service life.

0.3 In preparing this standard full consideration has been given to many factors involved, and to current practice regarding these, in the use of both ferrous and nonferrous materials.

0.4 Failure of the component parts of salt water piping systems may occur as a result of corrosion/erosion, otherwise known as impingement attack, arising from excessive turbulence. Such a condition may be brought about by poor design and/or workmanship or the use of too high a nominal water speed. Excessive water speed is a major factor and may arise as a result of poor design or misuse of the system. Failure may also occur by pitting resulting from deposit attack and cracking due to stress corrosion, or by general wastage in the case of ferrous systems.

0.5 Attention should therefore be given to the design, fabrication and installation of systems to ensure streamlined flow. In particular, abrupt changes in the direction of flow, mismatched pipe bores, tube bore protrusions and other restrictions to flow should be avoided.

0.6 At each stage of construction it is the responsibility of the user of this Indian Standard to ensure compliance with the requirements of the statutory authorities as applicable.

0.7 The Indian Standards referred to in this standard are given in Appendix A and a sample calculation for pressure loss in the system is given in Appendix B.

0.8 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part I) specifies requirements for the materials, design, installation, inspection and testing of salt water piping systems in ships, including all fittings which form parts of such systems, in which the pressure in the pipes does not exceed 1 MN/m^2 (10 bar)†.

1.2 For the purpose of this standard a salt water piping system includes all pipes and fittings from sea water inlet to discharge overboard but excludes all heat exchangers.

2. TERMINOLOGY

2.1 For the purpose of this standard, the following definitions, in addition to those given in IS : 812-1957‡ and IS : 3233-1965§, shall apply.

2.2 Design Pressure — The maximum pressure to which the system can be subjected when in service and is the value used in design calculations. This pressure may result from a combination of circumstances unlikely to occur under normal working conditions, for example, ship at its deep draught, discharge valves fully shut, pumps operating and relief valves set for normal working conditions.

2.3 Test Pressure — The pressure to which the system and its components are subjected under test conditions (*see* **8.2**).

2.4 Piping System — All pipes, pumps, valves and fittings from sea-water inlet to discharge overboard, but excluding all heat exchangers.

2.5 Flow Conditions — The expected conditions of water flow in individual parts or sections of the piping system. To meet varying design requirements three conditions are recognized:

a) *Continuous Flow* — Where the water in a system or part of a system is flowing continuously under the ship's normal operating conditions.

*Rules for rounding off numerical values (*revised*).
†1 bar = 10^5N/m^2 = 1 kgf/cm^2.
‡Glossary of terms relating to welding and cutting of metals.
§Glossary of terms for safety and relief valves and their parts.

b) *No-flow* — Air vents, and where a branch connection to a main pipe has its other end permanently closed. The water in that branch is regarded as having a no-flow condition.

c) *Intermittent Flow*— All systems and parts of the systems not covered by (a) and (b).

2.6 Purchaser — The shipowner or ship-operator according to the circumstances of the particular ship.

2.7 Manufacturer — The shipbuilder or authorised sub-contractor.

3. RATING OF SYSTEM

3.1 The design pressure rating of the system shall not be greater than 1 MN/m^2 (10 bar).

4. MATERIALS

4.0 Materials used in the component parts of salt water systems constructed in accordance with this standard, shall comply with one of the stated material standards or enumerated compositions as given in **4.1** to **4.4**.

4.1 Nonferrous Components — All copper alloys used in the manufacture of components for salt water piping systems shall conform to one of the Indian Standards or designated alloys given in Table 1.

4.2 Ferrous Components — The component is described as 'ferrous' if it is entirely ferrous or its main body is made of ferrous material. All ferrous alloys used in the manufacture of components for salt water piping systems shall conform to one of the Indian Standards or designated alloys given in Table 2.

4.3 Welding and Brazing Consumables — The welding and brazing consumables to be adopted in the construction of piping systems in accordance with this standard, shall be selected from those specified in the following Indian Standards:

a) *Ferrous Welding Consumables*

IS : 814 -1974*
IS : 1278-1972
IS : 1395-1971
IS : 5856-1970
IS : 6419-1971
IS : 6560-1972

**See* Appendix A for titles of referred standards.

b) *Nonferrous Welding Consumables*
   IS : 1278-1972
   IS : 5857-1970
   IS : 5898-1970

c) *Brazing Consumables*
   IS : 2927-1964

NOTE — Only the following alloys may be used:
BA-Cu-Ag10, BA-Cu-Ag16.

4.4 Nonmetallic Components

4.4.1 *Pipes* — Plastics and composites have limited application in salt water systems and are only to be used subject to agreement between the purchaser and the manufacturer.

4.4.1.1 *Flexible units or assemblies* — Suitable elastomers may be used for these components (*see* **7.2**).

4.4.2 *Pumps* — Certain pumps make use of synthetic elastomers for such purposes as the housing of scroll pumps and shoes of eccentric pumps. The precise materials shall be chosen to suit the conditions prevailing by the manufacturers for their proprietary products.

Wear rings for centrifugal pumps made from fibre reinforced plastics may be preferred to the lead-bronze material now in common use.

4.4.3 *Valves* — There is an increasing use of nylon for separate seat inserts in screw-down and check valves where erosive conditions are severe.

The bodies of some types of butterfly valves are covered with elastomer, for example, neoprene, of such thickness that the steel ring is only a support for the elastomer and can, therefore, be of mild steel not in contact with sea water.

4.4.4 *Orifice Plates* — Orifice plates and pressure reducing constrictions which may be subject to severe erosive conditions may be made of nylon.

5. DESIGN OF PIPELINE SYSTEM

5.1 General

5.1.1 In designing a salt water system it shall be noted that certain configurations and some types of fitting give an appreciable pressure loss and should be avoided if possible. Such measures shall have the added advantage of reducing the possibility of failure due to impingement attack, since local high losses in a pipe system will usually result in excessive turbulence in the flow fluid.

TABLE 1 NONFERROUS COMPONENTS

(Clause 4.1)

Indian Standard		Casting								Bar						Pipe				Sheet				Plate			Wire	
		318		318	305	28	4131	4131			7811					191		1545	1545								7608	
Component / Designated Alloy		Grade II	Cu 85,Sn5, Zn 3,Pb 3, Gunmetal	Grade I	Grade I — Al Bronze	Grade P Cu Sn 10 Phos Bronze	Ni Cu 31, Mn 1 Si 1, Fe 3	Ni Cu 29, Mn 1 Si 3, Fe 3	70/30 Cu Ni	Cu 80 Fe 5 Ni 5 Al 10 Al. Bronze		2% Al Brass	90/10 Cu Ni	70/30 Cu Ni	Ni Cu 31 Mn 2 Fe 2·5	Copper*	2% Al Brass	Cu Ni 10 Fe 1	Cu Ni 31 Mn1 Fe	2% Al Brass	90/10 Cu Ni	70/30 Cu Ni	Ni Cu 31 Mn 2 Fe 2·5	2% Al Brass	90/10 Cu Ni	70/30 Cu Ni	Grade II Phos Bronze	Ni Cu 31 Mn 2 Fe 2·5
Piping	Pipes															×	×	×	×	×	×	×		×	×	×		
	Flanges	†×	×	×	×																			×	×	×		
	Fasteners									×	×				×					×	×	×						
	Cast fittings	†×		×	×		×	×	×																			
	Wrought fittings									×	×	×	×	×	×					×	×	×		×	×			
Valves	Body, bonnet cover, disc (according to type of valve)	×	×	×	×		A ×	A ×	×																			
	Trim, disc and body seats, seals, hinge and ball	×	×	×	×		A ×	A ×	×	×	×				A ×													
	Internal fastenings, nuts, split, pins, locking pins, washers	×	×	×	×		A ×	A ×	×	×	×		×	×	A ×						×	×	A ×				×	A ×
	Stem	×	×	×	×	×	A	A		×	×				A													
Pumps	Body		×	×	×		A	A	×																			
	Impeller				×		A	A																				
	Shaft						A	A	×	×					A													
	‡Shaft sleeve		×	×											A													
	Wear rings	IS : 318 Grade 3 or Grade 4																										
	Internal fasteners, nuts, split pins, locking pins, washers	×	×	×	×		A ×	A ×	×	×	×	×	×	×	A ×						×	×	A ×				×	A ×
Strainers	Body	×	×	×	×		A	A	×								×	×	×		×	×		×	×	×		
	Mesh frame			×	×										A										×	×		
	Wire mesh																											A
	Perforated plate	×	×	×	×																×	×	A ×		×	×		
	Fastenings	×	×	×	×				×	×	×		×	×	A						×	×					×	
Weed Grids	Grids	×	×	×	×					×	×		×													×		
	Fastenings	×	×	×	×				×	×	×		×	×	A						×	×					×	

NOTE 1 — Where no standard is quoted the composition is to be agreed.

NOTE 2 — Wear rings for centrifugal pumps made from fibre reinforced plastic may be preferred to the lead-bronze material now in common use.

NOTE 3 — Where nickel copper alloys are used for the bodies of valves, pumps and strainers designated by the letter A, all items in these components, which are in contact with sea water, shall be of the same material.

*For airvents only.

†Also acceptable : Sn 3 to 4·5, Pb 6·5 to 9·0, Zn 8·5 to 11·0, Ni 2·0, Al 0·01 *Max*, Cu balance.

‡Stainless steel sleeves may be fitted to nonferrous shafts. Where aluminium bronze shafts are fitted with packing seals, gunmetal or stainless steel sleeves shall be fitted.

TABLE 2 FERROUS COMPONENTS

(*Clause* 4.2)

Indian Standard			Casting					Forging		Bar				Pipe						Sheet	Plate		
			1030	210	1865	2749	3444	1570	2004	2073		6603		1239 (Part I)	3601	5504	1239 (Part II)	4310	6392	1570		3039	1570
Component		Designated Material	Grade 3	Grade 25 or Grade 30	Grade SG 38/17	Flake Graphite Spheroidal Graphite	Grade 11 Austenitic Chromium Nickel Molybdenum Steel	CO 5, CO 7, C 10, C 15, C 20, C 25	Class 2		04 Cr 17 Ni 12 Mo 2 Stainless Steel	05 Cr 18 Ni 11 Mo3 Ti 20C Austenitic Steel	20 Cr 18 Ni 2 Martensitic Steel		HFW, HFS, CDS, ERW Grade 21 and 25 Butt Welded Grade 17	SFW Grade 25				CO 7, C 10, C 20	04 Cr 17 Ni 12 Mo 2 Stainless Steel 02 Cr 17 Ni 12 Mo 2		CO 7, C 10, C 20
Piping	*Pipes													×	×	×						×	
Piping	Pipe fittings		×	×	×	×		×	×								×	×		×			×
Piping	Flanges		×	×	×	×		×	×										×	×		×	×
Piping	†Fasteners																		×				
Valves	Body, bonnet cover, disc (according to type of valve)		×	×		×		×	×											×			×
Valves	Internal fittings	Valve spindle								×	×												
Valves	Internal fittings	Disc and body seats, hinge and ball																			×		
Pumps	†Body		×				×	×	×											×			×
Pumps	†Impeller					×	×																
Pumps	†Shaft						‡×					‡×	‡×										
Pumps	Shaft sleeve											§×											
Pumps	Wear rings						Either of the materials given in Table 1 may be used.																
Pumps	Internal fittings	†Nuts										×											
Pumps	Internal fittings	Split pins, locking pins					Only the materials given in Table 1 shall be used.																
Strainers	Body		×	×	×			×	×											×			×
Strainers	Mesh frame, wire mesh, perforated plate, internal fastenings						Only the materials given in Table 1 shall be used.																
Weed Grids	Grids		×			×	×																
Weed Grids	†Fastenings						×					×	×										

*All steel pipes shall be ordered in black condition. Pipes up to 50 NW can be of galvanized type if they are not subjected to hot bending. However 90/10 Cu Ni pipes may also be used.

†Any of the materials given in Table 1 may also be used.

‡For scroll pumps or for eccentric and shoe pumps where the shaft works in an elastomeric housing the shaft shall be made from IS : 1570-1971 Austenitic rust resisting steel.

§Is also acceptable : Cu 87, Sn 7, Zn 3, Pb 3 headed gun metal.

5.1.2 The diameter of each pipe run is determined from considerations of the water flow quantities and a permissible 'maximum velocity — pipe diameter' specification. The latter is usually related to the material of the piping and also depends upon whether the pipe is in a pump suction of discharge line. The suction piping is usually the larger in diameter and the pipe leads and fittings should be arranged to limit the pressure drop and ensure adequate flow of water to the pump suction.

5.2 Recommended Water Speeds

5.2.1 The water velocities for pipes should not exceed than those specified. It should be noted that excessive turbulence due to poor design and/or fabrication may result in failure at nominal velocities well below the values given. Where other materials are to be used, the water velocities shall be subject to agreement between the purchaser and the manufacturer.

Where plastics or plastics-lined pipes are to be used, the water velocities shall be subject to agreement between the purchaser and the manufacturer.

5.2.2 The maximum water velocity in heat exchanger tubes depends as much upon design as upon materials and is the responsibility of the heat exchanger designers.

5.2.3 It should also be noted that turbulence inside certain types of valves may result in local water speeds in excess of those in the pipeline of the same nominal bore.

5.3 Venting of Systems

5.3.1 Entrained air can cause corrosion and erosion of all parts of the system and particularly of components of pumps, valves and heat exchangers.

5.3.2 To limit the air in systems careful consideration shall be given to the following:

a) The number of bend branches and other fittings are to be kept to a minimum, at least one bend is to be introduced into the suction line between pump and the sea inlet to reduce transmission of pump noise into the sea.

b) Straight piping of at least 6 diameters length is to be fitted downstream of all turbulences raising components, that is, throttling and reducing valves, bends, tees, etc.

c) *Position of inlet boxes* — Much can be done to reduce air entrainment by giving careful attention to positioning of the sea inlet boxes. They shall be arranged so that they are not in the way of any line of excessive sea water turbulence due to the hull form nor placed in areas where air is likely to be released and accumulated owing to reduced pressure, for example, immediately beneath the bilge keel, or where water from other pump discharges will be entrained. Consideration shall be given to this aspect of design at the model tank testing stage; for instance, the depth of immersion at light draught shall be considered together with the angles of roll expected in adverse weather so that it shall not be possible for the boxes to emerge above the water line except perhaps in the most severe weather conditions. Even then the suction pipe shall still be completely immersed.

   If possible, the inlets shall be placed where the angles of run of the hull towards the stern are small.

   The effect of air entrainment during astern running at light draught shall also be carefully considered.

d) *Design of inlet boxes* — Ideally, the inlet box itself shall be streamlined as much as possible to reduce turbulence. A large rectangular box will tend to allow air to accumulate at the top and if the system suction is placed there, air will be ingested into the system. On the other hand, the conventional rectangular inlet box can be designed to be an effective separation chamber and it has the advantages of a position at the commencement of the system and flow velocities that are low. An arrangement such as an internal pipe to create a free surface shall be fitted and the removal of released air shall be accomplished by venting. The top of the chamber shall permit free passage of air to the vent.

e) *Weed grids* — Weed grids shall be designed so that any disruption of the flow of water is kept to a minimum. Weed grids shall be fitted at the ship's side on all sea water inlets to prevent large solids fouling the sea strainers. Preferably the grids should be mounted with the bars running in a fore and aft direction. The grid bar spacings should be about 25 mm minimum with the ratio of clear grid area to area of sea inlet valve or valves not less than 2:1. No part of a grid shall stand proud of the hull.

   Grids may be of cast or fabricated construction by agreement between the purchaser and the manufacturer. Grids shall be secured in position by copper alloy fasteners, securely locked, but shall be easily dismountable for drydock inspection.

f) *Air vents* — Arrangements shall be made for releasing air from the highest point in the inlet box. Where boxes are not on the bottom, air release may be through holes at the highest point connecting to the sea; in other cases vent pipes of adequate size may be used. Air vents in the form of pipes with steeply inclined runs shall lead from the highest point in the inlet box to a highest above the deepest load line of the ship. A shut-off valve shall be fitted between the vent line and the inlet box. The highest parts of the system shall also be provided with vents, and any positions where the water speed is low, should be vented.

Air release arrangements shall also be fitted on the pressure side of the system. The highest points of loops and heat exchangers are positions to consider. If system pressures are greater than the vent pipe head, it may be necessary to fit either constant bleed or automatic air release valves.

g) *Position of pumps* — Salt water pumps shall be placed as low as practicable in the engine room, preferably below the light load-line to enable natural flooding of the pump casing, but care shall be taken that the motor is kept sufficiently high to minimize the possibility of damage in the event of flooding.

5.4 Development of the Design — The development of the design shall be as given in **5.4.1** to **5.4.11**.

5.4.1 *Review Basic Design Data*

5.4.2 Assemble and study heat and flow balance sheets for principal machinery units served by the salt water piping system. List pump sizes recommended by suppliers for a typical duty, for example, diesel engine designers usually device pump head and flow quantities which are suitable for a typical installation. List standard modules for pump and heat exchanger components of the main system.

5.4.3 Study purchasers specifications and note special requirements for pipe materials, valves, joints, fabrication, erection, insulation (if any), maximum operating sea temperature, and ancillary ship services connected to the salt water systems, for example, fire, sanitary and ballast services.

5.4.4 Study Statutory and Classification Society requirements for the systems.

5.4.5 Establish if any special requirements are disclosed by the above procedures and if these conflict with standards normally followed by sub-contractors or builders. Initiate procedures to resolve points of difference and obtain outstanding information.

5.4.6 *Prepare Flow Diagrams*

5.4.6.1 Sketch single line flow diagrams indicating pumps, heat exchangers, machinery units and ancillary services specified. Add heat dissipation data, limiting temperature and known flow parameters and unit identification. The sketch shall desirably be made to roughly indicate differences in static heads which will be imposed on the flows. The use of scoops instead of inlet boxes is to be the subject of agreement between the purchaser and the manufacturer.

5.4.6.2 Add legend and a list of symbols and abbreviations which shall be used to identify pipeline fittings. Symbols used shall conform to relevant Indian Standards.

5.4.6.3 Add specified fittings to diagram, paying due regard to features mentioned elsewhere in this standard which will keep flow resistance to near the minimum for the pipe bore size adopted, and allow preferential flow, for example, through by-passes where required.

Attention is drawn to the need to avoid turbulent flow by the use of angled branches and large radii bends where possible.

5.4.6.4 Calculate flow quantities required in systems and matching pump capacities.

5.4.6.5 Establish maximum velocities acceptable in system and calculate matching pipe sizes to add to diagram.

5.4.6.6 Make first order estimate of probably straight pipe lengths and static heads, list fittings and calculate probably flow resistance. This calculation shall require to be kept under review as the design is progressed. If the system resistance is higher than acceptable, the pipe bores shall be reconsidered and the calculation adjusted until the results are satisfactory.

5.4.6.7 Results obtained shall be checked with an economic analysis of the cost of pumping the quantity required with various flow resistance pumps, and pipe size to ensure they are compatible.

5.4.7 *Isometric Sketches*

5.4.7.1 Flow paths can be readily visualized and piping layout generally decided by means cf such sketches, which can be supplementary and/or alternative to flow diagrams and piping arrangement drawings.

5.4.7.2 Such isometric sketches shall show the general arrangement of equipment and piping, with limited detail, to determine optimum layout and nozzle orientation on equipment. Instrumentation requirements for pipe connections may also be determined.

5.4.7.3 Component/unit identification numbers shall be added on these sketches, and/or flow diagrams, to facilitate ordering and drawing procedures.

5.4.8 *Ordering of Equipment*

5.4.8.1 Lists of special fittings required — for example, strainers, special valves, control valves, spectacle pieces, orifice plates — shall be prepared from the available sketches. Preliminary requisitions for such fittings and for pumps (with suitable margins on head and capacity to provide for contingencies) piping, etc, shall be issued, if this is necessary to ensure satisfactory delivery. Such requisitions shall be kept under review as the systems are developed.

NOTE — Attention is drawn to the requirements of the Statutory Authorities Classification Societies regarding ships side valves.

5.4.9 *Piping Layout*

5.4.9.1 If model techniques are not employed, nor alternative, permanent records of the layout found acceptable, it will be necessary to prepare pipe arrangement drawings. Such drawings shall:

1) determine scale and show orientation;
2) show the essential minimum detail of associated equipment, for example, heat exchangers and pumps from suppliers drawings, and ship structure to determine system component locations and clearance. Such outlines shall contrast with piping shown;
3) provide clearances for all equipment — for example, for tube-stack removal, motor access and equipment maintenance — and for access to machinery parts, for example, main engine holding down bolts;
4) provide accessibility to all system components which may require manipulation, inspection and maintenance;
5) provide easily portable sections — for example, short bends or make-up pieces — to facilitate removal of heat exchanger water boxes, etc;
6) show piping by single line if permissible except where double line is essential to demonstrate clearances;
7) arrange pipe runs on fore and aft line, or at 90° thereto, except where large and expensive lines justify the minimum length between two points being used. Maintain different elevations between fore and aft, and athwartship runs where possible;
8) give preference to large bore pipe runs to give direct runs where possible and minimize fabrication costs. Such pipes to be routed to take advantage of ship structure for supports and pipe support and anchor points to be shown on drawing;

9) keep the number of joints to a minimum practicable number;

10) provide that pipes are laid in such a way that they shall not touch the tank top. It is advisable to give sufficient clearance between the pipes and the tank top to avoid pipes submerging in bilge water and also for inspection of the tank top and also opening flanges;

11) show the essential minimum details of seatings of equipment, ladder ways, etc, to enable to design the fully coordinated pipe layout;

12) specify that lifting eyes are provided for enabling motors of pumps, etc, to be removed;

13) show the bends for pipes, when running in straight length to compensate for expansion and contraction of the pipes;

14) show suitable openings to be provided on floor plates wherever valves are fitted below floor;

15) provide that where a closing length is to be made from dimensions lifted from place, the location shall be easily accessible;

16) indicate one anchor point at an interval of 3 m, also supports in critical positions, for example, where arranged to avoid imposition of loadings on pumps branches or at flexible pipe connections;

17) avoid pockets and vertical loops where possible, but provide additional drains and vents where such configurations are unavoidable;

18) provide pipe flexibility in way of orifice plates or temporary line blanks which may have to be removed for service adjustments. Where orifice plates are used for permanent control of flow a straight length of pipes of not less than 6 diameters shall be fitted downstream of the plate;

19) provide and indicate location of instrumentation system connections;

20) show enlarged detail section to indicate orientation and flow direction through special control valves or other fittings which are of unusual construction;

21) show component unit numbers of all pipes and fittings;

22) provide that such drawings are annotated to indicate non-standard joints, materials, fittings, testing procedures, purchaser's special requirements, etc;

23) include essential dimensions for locating pipe centre lines in the ship where these may be required to produce pipe fabrication sketches or pipe support dimensions; and

24) clearly indicate terminal points of lines where continuations will be arranged by other piping designers, and detail connecting flanges.

5.4.10 *System Check* — On completion of the drawings the system resistance losses shall be re-calculated, the pipe and fitting schedules reviewed, and requisitions for equipment confirmed.

5.4.11 *Pressure Loss Through Proprietary Items* — The pressure loss through proprietary items, such as coolers may be obtained from the manufacturers specification. The extra losses to be determined are those occuring in the pipes, valves, bends and other fittings and may be calculated according to the method given in Appendix B.

6. MIXED FERROUS AND NONFERROUS SYSTEMS

6.1 Where systems use different materials which are in contact with each other, for example, nonferrous pipes with cast iron valves, accelerated corrosion of the ferrous component shall occur.

The problems involved are outlined in Appendix C.

7. PIPEWORK FLEXIBILITY, SUPPORT AND INSTALLATION

7.1 Flexibility of Piping Systems

7.1.1 Piping systems shall be designed with adequate flexibility so that expansion of the piping and machinery, vibration and working of the ship shall not result in overstress of the system or leakage at joints.

7.1.2 Flexibility shall normally be provided by the use of plain piping bent to normal specified radius, loops and offsets in the piping. Loops or any other parts of pipework subject to excessive working shall not be made of aluminium brass.

7.1.3 Where space limitations prevail or where piping is to be attached to resiliently mounted machinery use may be made of flexible pipes or bellows expansion pieces, preferably made of a suitable elastomer. They shall be installed in an unstressed condition.

7.1.4 Pressure of fluid in a piping system can result in distortion particularly in way of bends and flexible units if adequate anchorage is not provided. Attention is drawn to the necessity of making such provision as stated in **7.2**.

7.2 Flexible Piping Units or Assemblies

7.2.1 The design and construction of these components shall be suitable for the pressure, vacuum and temperature under all conditions likely to occur in service, including ambient temperature and shall also be capable of absorbing the movements imposed by attached machinery and pipework.

7.2.2 The material of these components, including any fittings if separately attached, shall be suitable for containing sea water and be compatible with the material of the piping system to which they are attached.

7.2.3 Resistance to damage by fire or other means shall be considered and where deemed necessary a suitable shield fitted around the flexible components (*see also* **0.6**).

7.2.4 Flexible pipes should be limited to only one compartment of the ship and that too localized to small lengths only.

7.2.5 Elastomer assemblies shall not be painted.

7.3 Pipe Supports

7.3.1 *General Design*

7.3.1.1 Pipelines shall be routed to enable the surrounding structure to provide logical points of support, anchorage, guidance or restraint. Supporting of the largest of critical piping systems shall take priority over others and the location of supports and anchors shall be shown on arrangement drawings.

7.3.1.2 The design of supports is to be capable of adequately supporting the piping system without undue distortion. In addition to pipeline gravitational loads the supports shall provide for concentrated loads imposed by valves and risers, for axial loadings due to expansion and the pressure of fluid, and for enertia effects due to ship movements. Hangers for supports shall be provided close to concentrated weights, at horizontal changes in line direction, and on or adjacent to pipe risers.

7.3.1.3 Pipework adjoining flexible units shall be supported as closely as possible to the flexible unit. The supports shall be designed to prevent the pressure loads transmitted by the flexible unit distorting the attached pipework and equipment.

Where steel or cast iron pipes are connected by proprietary couplings allowing flexibility, their installation, supports and anchorage must be such as to accommodate changing alignment in service. The couplings shall only be used subject to agreement between the purchaser and the manufacturer.

7.3.1.4 Supports for metallic pipes shall be placed at intervals of approximately 3 m but where the configuration of pipework is complex additional hangers shall be fitted.

7.3.1.5 Plastic pipes shall be supported continuously where possible.

7.3.1.6 All pipework shall be examined during the sea trial to determine whether additional hangers are necessary due to unforeseen vibrations.

7.3.2 *Detail Design*

7.3.2.1 Guidance may be taken from IS : 4693-1968 in designing of supports.

7.3.2.2 Supports for nonferrous pipes are to be lined with a soft packing strip, free from ammoniacal compounds, to prevent chafing and stress corrosion and to permit free expansion and contraction between anchors.

7.3.2.3 The use of toe hangers or supports, where the stressed leg is welded directly to the supporting structure without flanging, is not recommended due to the weakness of this type of attachment.

7.3.2.4 If plastic pipes are used, the type of supports shall be subject of special consideration and agreement between the purchaser and the shipbuilder.

7.4 Piping Installation

7.4.1 *Pipe Jointing*

7.4.1.1 *General* — Jointing material shall conform to Grade C of IS : 2712-1971. Other materials may be adopted by agreement between the purchaser and the manufacturer.

Jointing material shall be pre-cut and so dimensioned that it will not project into the bore of the pipe. It is recommended that the gaskets be full face and located on the bolts except where raised face flanges are in use.

7.4.1.2 *Jointing in fire mains* —Jointing in fire mains is subject to the requirements of Statutory Authorities Classification Societies. The material to be used shall be as follows:

a) Compressed asbestos fibre conforming to IS : 2712-1971 Grade C for jointing not greater than 2 mm thick.

b) Other material not greater than 1 mm thick. Chloroprene or materials having similar melting points shall not be used.

7.4.2 *Pipe Erection*

7.4.2.1 Flange faces shall be closely mated and bolt holes in alignment before making up the joints. The pipes shall not be strained into position in order to make them fits. Pipes which do not fit satisfactorily shall be returned to the workshop for correction and re-stress relieving, where necessary.

7.4.2.2 Mating pipes, valves and fittings shall be installed with their bores concentric and in line and care taken to ensure that any jointing fitted does not protrude into the bore.

7.4.2.3 Care shall be taken with alignment of piping when making screwed, brazed or welded joints.

7.4.2.4 The installation of bellow pieces or flexible units shall be carefully carried out to ensure that they are not pre-stressed.

7.4.2.5 The closing length of piping shall be manufactured to a sufficient degree of accuracy so that it can be fitted in place without undue manual effort and so that the flanges are closely mated and the bolts can be inserted freely. If there is any mis-alignment which cannot be corrected manually, the pipe shall be removed for correction and subsequent stress relieving, if of nonferrous material shall be carried out.

7.4.2.6 Closing lengths shall not be finally connected until the system has been inspected as specified in **8.2.** Flange joints shall be unfastened with bolts loosely in place.

8. INSPECTION AND TESTING

8.1 Component Inspections and Tests Before Installation

8.1.1 *Shop Inspection* — The following inspections shall be carried out before pressure testing:

a) All components shall be checked to ensure that they are correct and in accordance with drawings, especially details of terminals and materials.

b) All components shall be visually examined for faults and irregularities and shown to be clear of scale or internal deposits. Instruments shall be available for internal inspection of branch attachments.

c) Welded and brazed joints shall be examined to ensure that fillets are regular and continuous in form. Wherever practicable it shall be established that there is no lack of root penetration, or evidence of non-fusion or burn through/excessive penetration, of the pipe in way of the joint.

d) In the case of steel flanges welded to cupro-nickel pipework, penetration of iron to the surfaces in contact with sea water shall be checked by means of the 'ferricyanide test', after cleaning the area to be considered, according to the following procedure:

1) Swab with dilute hydrochloric acid (HCl), and
2) Swab with a solution of potassium ferricyanide [$K_3Fe(CN)_6$].

Aqueous solutions are used and the concentrations are unimportant. A ratio of 1 : 4 of concentrated HCl to water and a 10 percent solution of ferricyanide is suitable.

Iron penetration is shown by a blue discolouration and any indication of the presence of iron is unacceptable. Simple washing is adequate to remove residue from acceptable joints.

8.1.2 *Shop Test* — Each completed pipe and fitting shall be hydraulically tested to 3 bar or to twice the maximum pressure to which the system can be subjected under service conditions whichever is the greater.

8.1.2.1 *Hydraulic tests and capacity tests for pumps*

a) All pumps intended for essential services are to be tested hydraulically and for capacity ;
b) Pump and housings and cylinders are to be tested to $1\frac{1}{2}$ times the working pressure; and
c) Pumps capacities are to be checked with the pump running at rated speed with rated pressure head. Capacity test may be dispensed with, when previous satisfactory tests have been carried out on similar pumps.

8.1.2.2 The completed pipes and fittings shall be tested with fresh mains water with filling, air evacuation and test gauge connections provided. The test pressure shall be maintained for not less than two minutes after the filling valve is closed to demonstrate the integrity of all connections. The test shall be repeated after the rectification of any defects. After testing all such components shall be drained and all terminal blanked before the component is despatched to the ship.

8.2 System Inspections and Tests After Installation

8.2.1 *System Inspections After Installation* — Before any testing is carried out the system shall be inspected to check that:

1) pipes are galvanized and painted where required. The colour of the paint on the pipes shall be as specified in relevant Indian Standards;

2) the installation is in accordance with the pipe arrangement drawings;
3) where polluted water is admitted for basin trials consideration shall be given to inhibitive chemical treatment;
4) the location and fitting of supports and hangers are adequate;
5) the joints are accessible for maintenance;
6) the fittings are installed correctly for the required direction of flow, especially valves and strainers;
7) the valves are accessible for operation and maintenance;
8) loads are not imposed on pump castings and other fixed components due to distortion of pipes or lack of support of adjoining fittings;
9) all valves and necessary remote control can operate through their full limits open-shut-open;
10) all bellows pieces and flexible pipes are installed correctly within the operating limits specified;
11) all continuity strips, if specified, are installed;
12) in cases where incomplete systems are to be tested, protection blanks are replaced with metal blanks or plugs. The complete system is to be subsequently tested;
13) pumps are fitted with required suction and discharge pressure gauges; and
14) valves are correctly labelled.

8.2.2 *System Tests After Installation* — After all inspections have been carried out and rectifications made the system shall be tested in accordance with the following procedure. Where the system is extensive, preliminary air testing may be carried out in order to detect large leaks before carrying out the hydraulic test:

a) In order to protect surfaces of copper alloy systems the first filling of a new system shall be with clean sea water, or if not available fresh mains water. Distilled water or contaminated deck or river water shall not be used;
b) Each pump shall be primed before starting basin trials;
c) The system shall be circulated with water at the maximum pressure attainable by the pumps under existing conditions;
d) All air valves and air ejectors shall be operated to ensure that air is released from high points;
e) The system shall be examined for leaks from joints and glands;

f) A note shall be made of undue noise and vibration, and additional supports fitted where necessary; and

g) After completion of the basin trials the systems shall be flushed with mains water and drained as far as practicable.

8.2.3 *Records* — Records signed by the inspector shall be kept for all inspection and tests.

8.3 Sea Trials

8.3.1 *System Tests* — The system shall be tested in accordance with the following procedure:

a) Each pump shall be primed before starting;

b) The system shall be circulated with water at the maximum pressure attainable by the pumps under normal service conditions;

c) All air valves and air ejectors shall be operated to ensure that air is released from high points;

d) The system shall be examined for leaks from joints and glands; and

e) A note shall be made of undue noise and vibration, and additional supports fitted where necessary.

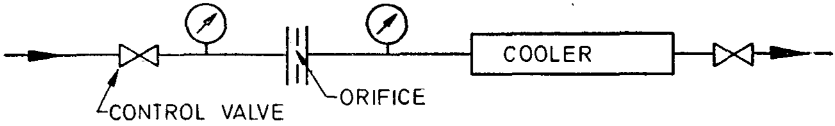
8.3.2 *Setting Up Correct Flows in Salt Water Circulating Systems* — Notwithstanding all precautions taken during design and installation considerable trouble may be experienced at sea by failures of pipes and fittings due to corrosion/erosion. It is, therefore, very important that the system shall be correctly adjusted during sea trials so that design flows are achieved through the various pipelines.

This can be achieved by any one of the following methods:

a) To fit temporary orifice plates with flow measuring devices at each heat exchanger [*see* Fig. 1 (a)], the control valves being finally fitted with gags or other restraining devices so that they cannot be opened or closed beyond the correct set point; and

b) By-pass and dump valves may have to be arranged to compensate for sections of the system being shut down [*see* Fig. 1 (b)].

With the system operating at design pressure the pump throughout shall be according to design requirements.



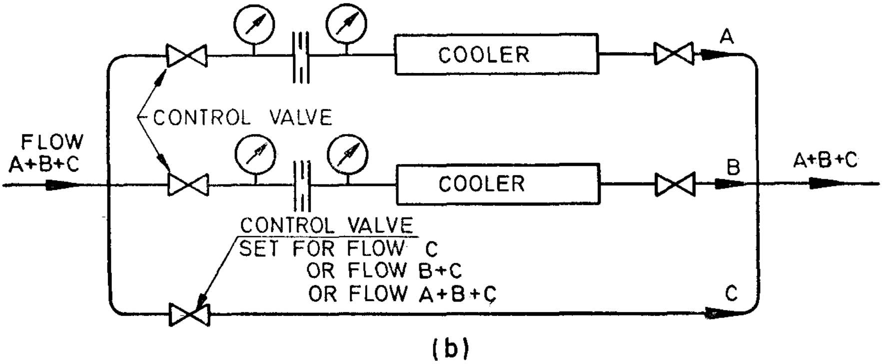


FIG. 1 SETTING UP CORRECT FLOWS IN SALT WATER CIRCULATING SYSTEMS

APPENDIX A

(*Clause* 0.7)

LIST OF INDIAN STANDARDS

IS : 28-1969	Specification for phosphor bronze ingots and castings (*second revision*)
IS : 191-1967	Specification for copper (*second revision*)
IS : 210-1970	Specification for grey iron castings (*second revision*)
IS : 305-1961	Specification for aluminium bronze ingots and castings (*revised*)
IS : 812-1957	Glossary of terms relating to welding and cutting of metals
IS : 814-1974	Specification for covered electrodes for metal arc welding of structural steel (*fourth revision*)
IS : 1076-1967	Specification for preferred numbers (*first revision*)

IS : 1239 (Part I)-1973 Specification for mild steel tubes, tubulars and other wrought steel fittings : Part I Mild steel tubes (*third revision*)

IS : 1239 (Part II)-1969 Specification for mild steel tubes, tubulars and other wrought steel fittings : Part II Mild steel tubulars and other wrought steel pipe fittings (*second revision*)

IS : 1278-1972 Specification for filler rods and wires for gas welding (*second revision*)

IS : 1323-1966 Code of practice for oxy-acetylene welding for structural work in mild steel (*revised*)

IS : 1385-1968 Specification for phosphor bronze rods and bars, sheet and strip, and wire (*first revision*)

IS : 1395-1971 Specification for molybdenum and chromium molybdenum low alloy steel electrodes for metal arc welding (*second revision*)

IS : 1536-1967 Specification for centrifugally cast (spun) iron pressure pipes for water, gas and sewage (*first revision*)

IS : 1537-1960 Specification for vertically cast iron pressure pipes for water, gas and sewage

IS : 1538-1969 Specification for cast fittings for pressure pipes for water, gas and sewage (*first revision*)

IS : 1570-1961 Schedules for wrought steels for general engineering purposes

IS : 1865-1968 Specification for iron castings with spheroidal or nodular graphite (*first revision*)

IS : 1879-1961 Specification for malleable cast iron pipe fittings

IS : 2004-1970 Specification for carbon steel forgings for general engineering purposes (*first revision*)

IS : 2633-1972 Methods of testing weight, thickness and uniformity of coating on hot dipped galvanized articles (*first revision*)

IS : 2712-1971 Specification for compressed asbestos fibre jointing (*first revision*)

IS : 2749-1964 Specification for austenitic iron castings

IS : 2927-1964 Specification for brazing alloys

IS : 2986-1964 Specification for steel castings for marine engines and boilers

IS : 3039-1965 Specification for structural steel (shipbuilding quality)

IS : 3076-1968 Specification for low density polyethylene pipes for potable water supplies (*first revision*)

IS : 3233-1965 Glossary of terms for safety and relief valves and their parts

IS : 3444-1966 Specification for corrosion resistant steel castings

IS : 3589-1966 Specification for electrically welded steel pipes for water, gas and sewage (200 to 2 000 mm nominal diameter)

IS : 3601-1966 Specification for steel tubes for mechanical and general engineering purposes

IS : 4131-1967 Specification for nickel-copper alloy castings

IS : 4310-1967 Specification for weldable steel pipe fittings for marine purposes

IS : 4682 (Part I)-1968 Code of practice for lining of vessels and equipment for chemical processes : Part I Rubber lining

IS : 4682 (Part II)-1969 Code of practice for lining of vessels and equipment for chemical processes : Part II Glass enamel lining

IS : 4682 (Part III)-1969 Code of practice for lining of vessels and equipment for chemical processes : Part III Lead lining

IS : 4682 (Part IV)-1969 Code of practice for lining of vessels and equipment for chemical processes : Part IV Plasticized PVC

IS : 4682 (Part V)-1907 Code of practice for lining of vessels and equipment for chemical processes : Part V Epoxide resin lining

IS : 4693-1968 Specification for steel accessories for marine piping systems

IS : 4984-1972 Specification for high density polyethylene pipes for potable water supplies (*first revision*)

IS : 5493-1969 Dimension for wrought copper and copper alloy tubes

IS : 5504-1969 Specification for spiral welded pipes

IS : 5856-1970 Specification for corrosion and heat-resisting chromium-nickel steel solid welding rods and bare electrodes

IS : 5857-1970 Specification for nickel and nickel alloy bare solid welding rods and electrodes

IS : 5898-1970 Specification for copper alloy bare solid welding rods and electrodes

IS : 6419-1971 Specification for welding rods and bare electrodes for gas shielded arc welding of structural steels

IS : 6560-1972 Specification for molybdenum and chromium-molybdenum low alloy steel welding rods and base electrodes for gas shielded arc welding

IS : 7608-1975 Specification for phosphor bronze wires (for general engineering purposes)

IS : 7811-1975 Specification for phosphor bronze rods and bars

APPENDIX B

(*Clauses* 0.7 *and* 5.4.11)

TYPICAL PRESSURE LOSS CALCULATIONS FOR SEA WATER COOLING SYSTEM OF A DIESEL ENGINE

B-1. EXAMPLE

B-1.1 The main and auxiliary diesel engine in a ship are supplied with sea water from a common sea inlet as shown in the sketch of the cooling system (*see* Fig. 2). The losses in the main engine cooling system are evaluated as under:

a) Material of pipe — 90/10 Cu-Ni alloy

b) Pump output:

1) Main engine — 100 m^3/h
2) Auxiliary engine — 35m^3/h

c) Kinematic viscosity of sea water — $0{\cdot}85 \times 10^{-6} m^2/s$ at 30°C

d) Obtain the flow parameters in the various branches as given below (*see* Fig. 2):

	Branches			
	(AB)	*(BD)*	*(DG)*	*(DH)*
1) Quantity of flow (m^3/h)	135	100	60	40
2) Pipe dia (m)	0·175	0·125	0·1	0·08
3) Cross section area of pipe (m^2)	0·024	0·012 27	0·007 85	0·005 02
4) Velocity of flow (m/s)	1·562 5	2·263 8	2·123	2·213
5) Velocity head equivalent $\frac{(V^2)}{(2g)}$	0·124	0·261	0·229	0·249
6) Reynold's No. $(Re = \frac{V \times d}{\nu})$	3·216 10^5	3·329 10^5	2·497 10^5	2·08 10^5
7) Friction coefficient (f)	0·018	0·019	0·019 3	0·019 5

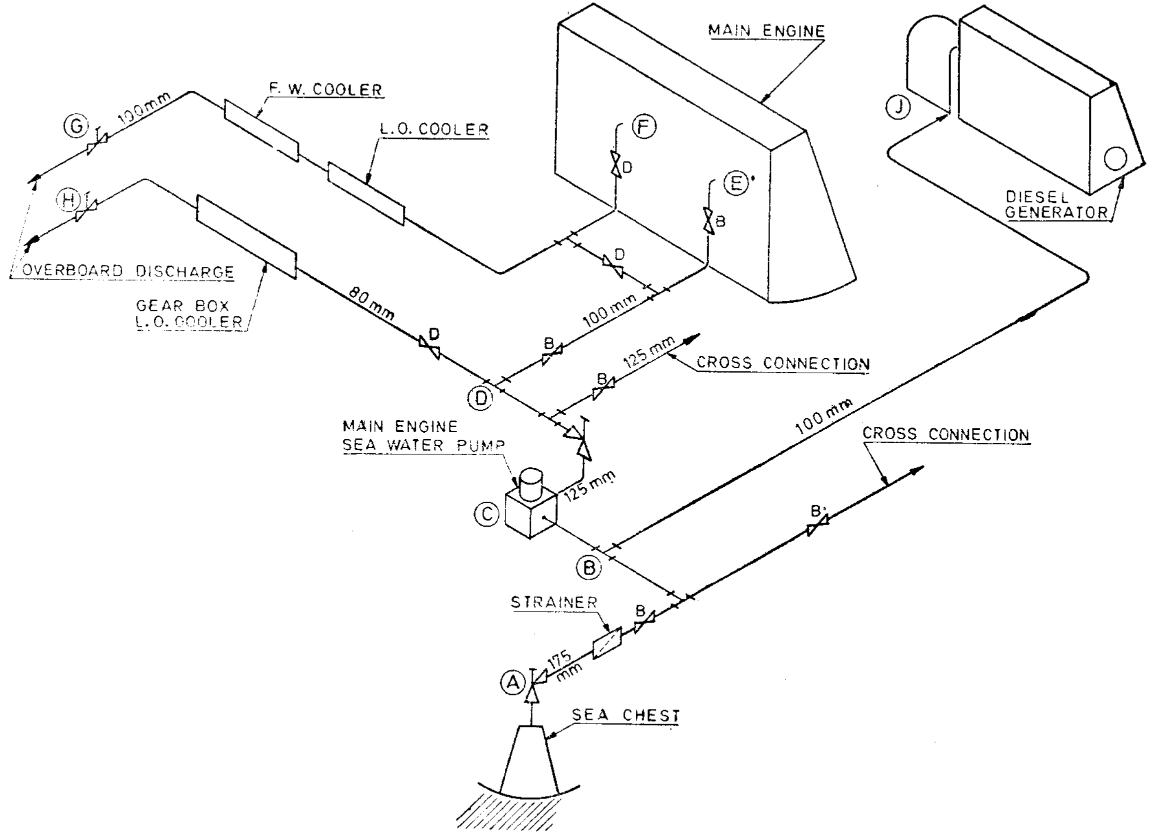


FIG. 2 ISOMETRIC VIEW OF PIPING LAYOUT

e) Losses on pump suction end —
Sea inlet to pump suction

1) *Branch AB*:

	Loss Coefficient
i) Inlet from sea chest sudden contraction $d/D = 0$	0·5
ii) Angle valve (globe type) at sea inlet	2·3
iii) Strainer	2·4
iv) Butterfly valve	0·4
v) T-joint (175 × 175 × 175) flow from main to branch (no flow in cross connection branch)	1·0
vi) T-joint (175 × 125 × 100) dividing flow, loss coefficient will be sum of branch loss and sudden contraction loss	1·08
vii) Straight pipe length $AB = 1{\cdot}5$ m	0·154
Total for Branch AB : K_{AB}	7·834

$$K_{AB} = \frac{f.l}{D} = \frac{(0{\cdot}018)\ (1{\cdot}5)}{(0{\cdot}175)} = 0{\cdot}154$$

2) *Branch BC*:

Straight pipe length $BC = 0{\cdot}5$ m

$$K_{BC} = \frac{(0{\cdot}019)\ (0{\cdot}5)}{(0{\cdot}125)} = 0{\cdot}076$$

$$\text{Loss for branches } AB \text{ and } BC = K_{AB}\frac{(V_{AB}{}^2)}{(2g)} + K_{BC}\frac{(V_{BC}{}^2)}{(2g)}$$
$$= (7{\cdot}834)\ (0{\cdot}124) + (0{\cdot}076)\ (0{\cdot}261)\text{m}$$
$$= 0{\cdot}97 + 0{\cdot}019\,83 = 0{\cdot}989\,83\text{m}$$

Summation of losses from sea inlet to pump suction

Vapour pressure	0·449 m
Branches AB and BC	0·989 m
Static head	1·5 m
Total	2·938 m

f) Losses on pump discharge end

1) *Branch CD*:

i) 90° bend, radius $R/D = 2$	0·14
ii) Angle valve (globe type)	2·6
iii) T-joint (125 × 125 × 125) no flow in branch	0·2
iv) T-joint (125 × 100 × 80) dividing flow, branch loss component (Sum of branch loss and sudden contraction loss)	0·73
v) Straight pipe length 2·5 m	0·38

$$K_{CD} = \frac{f.l}{d} = \frac{(0{\cdot}019)\ (2{\cdot}5)}{(0{\cdot}125)} = 0{\cdot}38$$

Total for branch *CD* 4·05

$$\text{Loss for branch } CD = K_{CD}\frac{(V_{CD}^2)}{(2g)} = (4{\cdot}05)\ (0{\cdot}261) = 1{\cdot}057$$

2) *Branch DG*:

i) 2 butterfly valves (2 × 0·6)	1·2
ii) 2 T-joints (100 × 100 × 100) no flow in branch – 2 × 0·2	0·4
iii) Loss in air coolers *EF* assumed to be 1·8, with flow velocity same as in branch *DG*	1·8
iv) Loss in lub oil cooler (assumed)	2·4
v) Loss in FW cooler (assumed)	2·5
vi) Diaphragm valve	1·0
vii) Globe valve (discharge overboard)	7·0
viii) Sudden enlargement $d/D = 0$	1·0
ix) Straight pipe length 9·5 m	1·805

$$K = \frac{(9{\cdot}5)\ (0{\cdot}019)}{(0{\cdot}1)}$$

Total 19·105

$$\text{Loss for branch } DG = K_{DG}\frac{(V_{DG}^2)}{(2g)} = (19{\cdot}105)\ (0{\cdot}229)$$

$$= 4{\cdot}374 \text{ m}$$

3) *Branch DH*:

i) T-joint (125 × 100 × 80) dividing flow, straight flow component (Sum of loss in Tee and sudden contraction)	0·23
ii) Diaphragm valve	1·0
iii) Gear box lub oil cooler (assumed)	3·0
iv) Globe valve (discharge overboard)	7·5
v) Sudden enlargement ($d/D = 0$)	1·0
vi) Straight pipe length 7·5 m	1·83
Total	14·56

$$K = \frac{(7{\cdot}5)\ (0{\cdot}019\,5)}{(0{\cdot}08)} = 1{\cdot}83$$

Loss in branch DH = (14·56) (0·249) = 3·62 m

This loss is less than that in the parallel branch DG (4·374 m), and can be neglected while evaluating the total loss.

Summation of losses on discharge end:

Branch CD	1·057 m
Branch DG (as this is greater than DH)	4·374 m
Static head between pump discharge and overboard valve	1·315 m
Total head loss on discharge side	6·746 m

g) Delivery head of pump = 21 m
Net head available = 21 − 6·746 = 14·254 m

h) Head loss in system:

Suction	2·938 m
Discharge	6·746 m
Total loss	9·684 m

Conclusion:

The pressure loss in the suction line is 2·489 m of water. The vapour pressure of sea water at 30°C is 4·4 KN/m² which corresponds to 0·449 m of water. The maximum suction lift of the pump is 6 m, which is greater than the total loss on the suction end (2·489 + 0·449) of 2·938 m, hence the pump will take suction satisfactorily.

The pressure loss on the discharge end is 6·746 m and gives us a net head of (21 − 6·746 m) 14·254 m.

The total loss in the system is (2·938 + 6·746) = 9·684 m of water.

B-2. The various loss-coefficients for pipe joints, fittings and valves used in these calculations have been taken from Fig. 3 to 16.

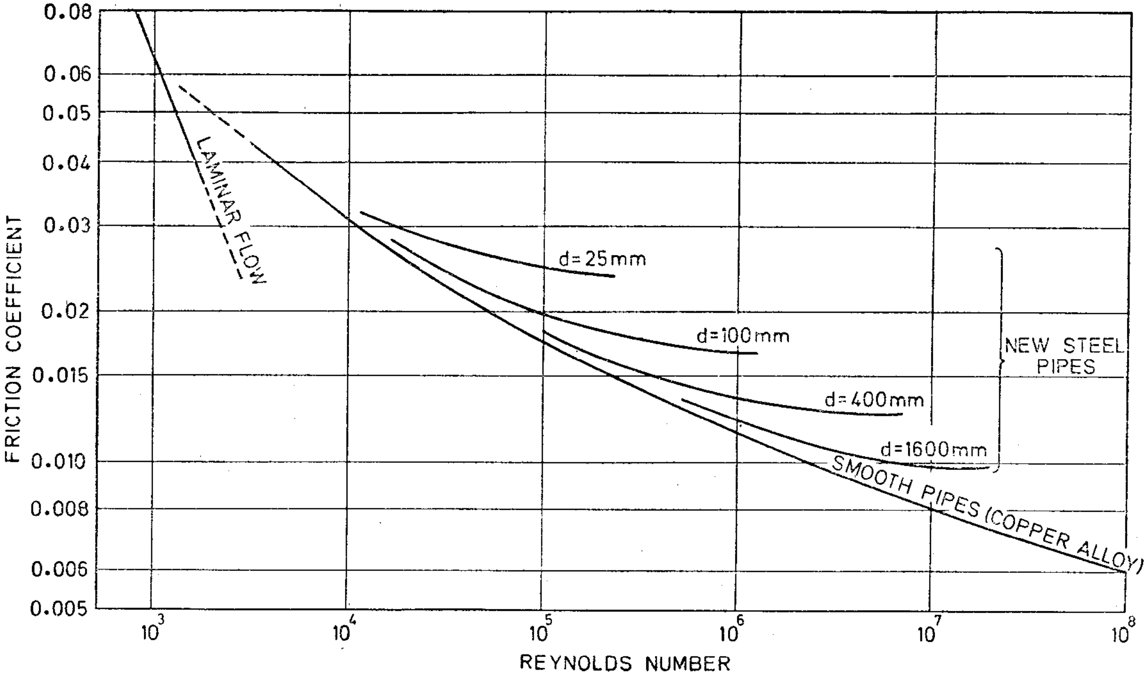


FIG. 3 PIPE FRICTION COEFFICIENT

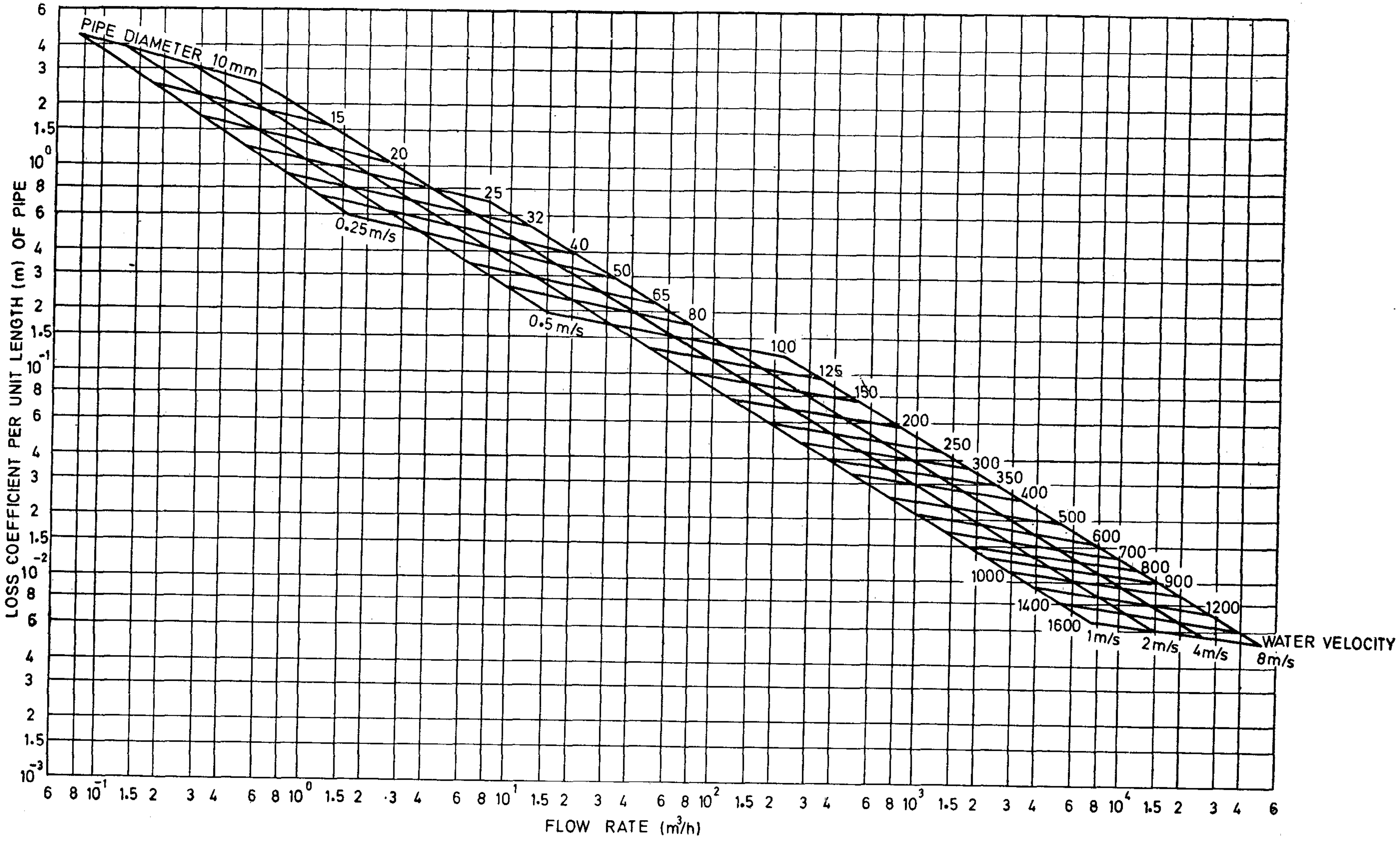


FIG. 4 FRICTION LOSS IN 'SMOOTH' COPPER ALLOY PIPES (WATER 20°C)

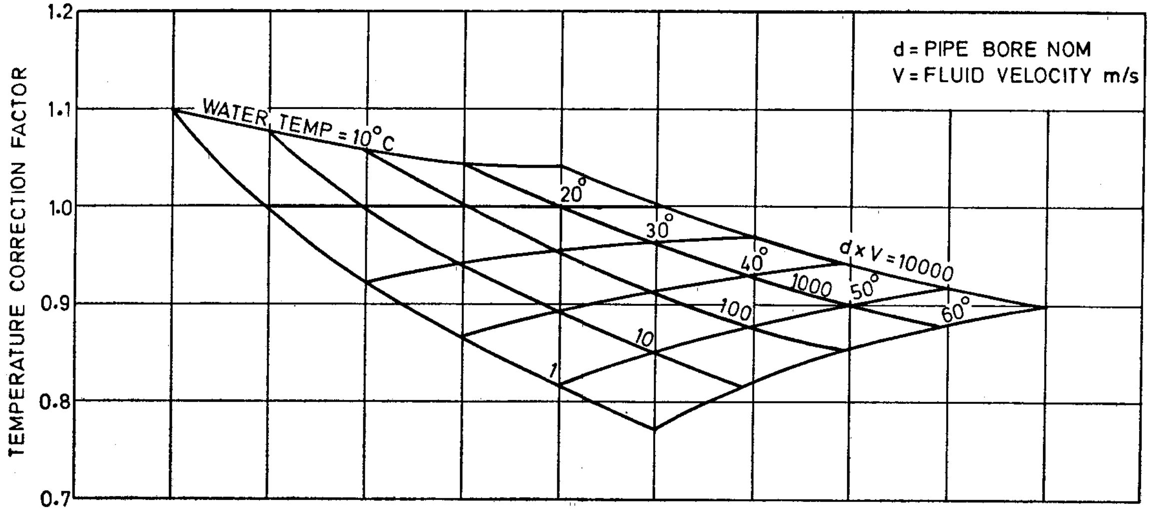


FIG. 5 TEMPERATURE CORRECTION FACTOR FOR LOSS IN 'SMOOTH' COPPER ALLOY PIPES

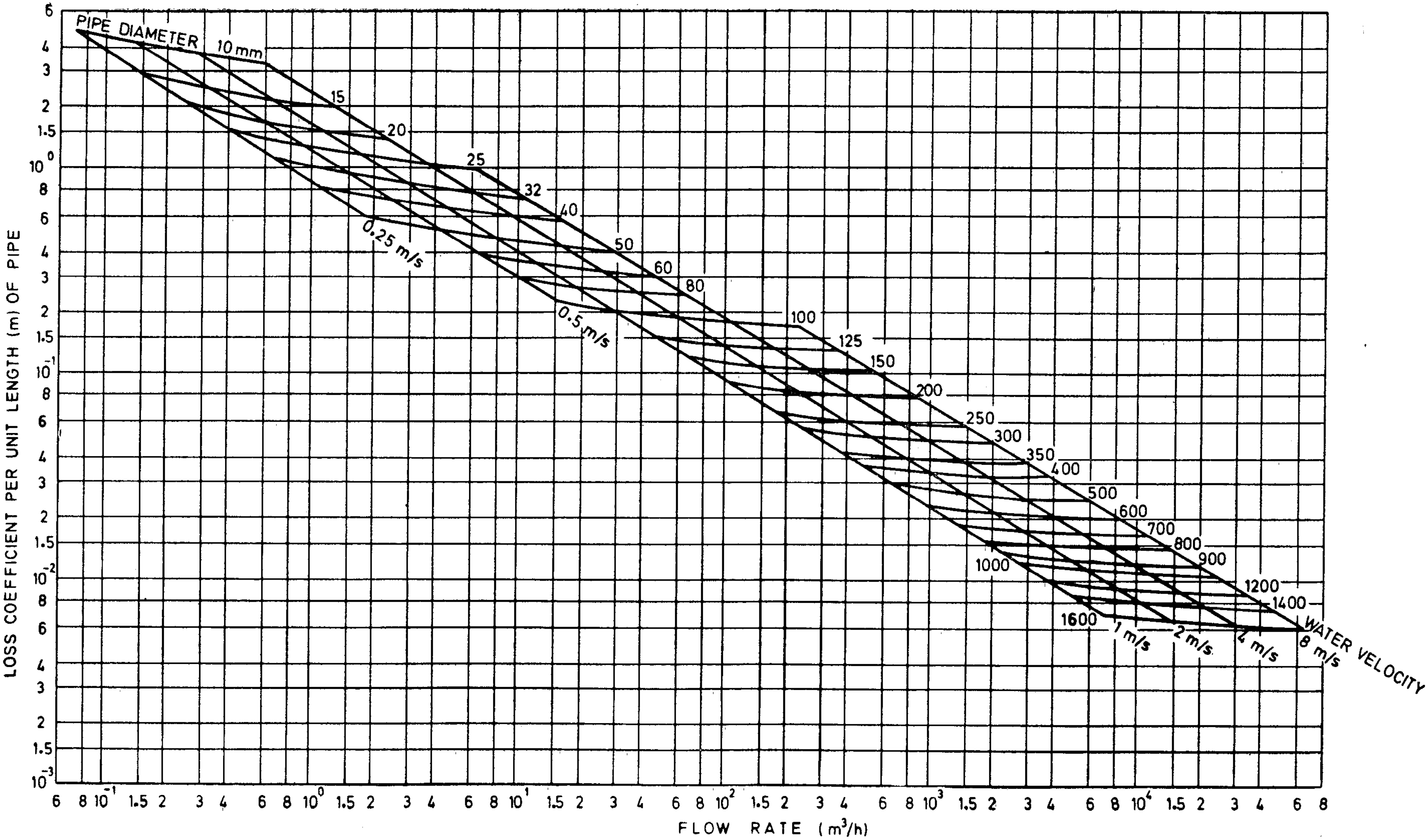


FIG. 6 FRICTION LOSS IN NEW STEEL PIPES (WATER 20°C)

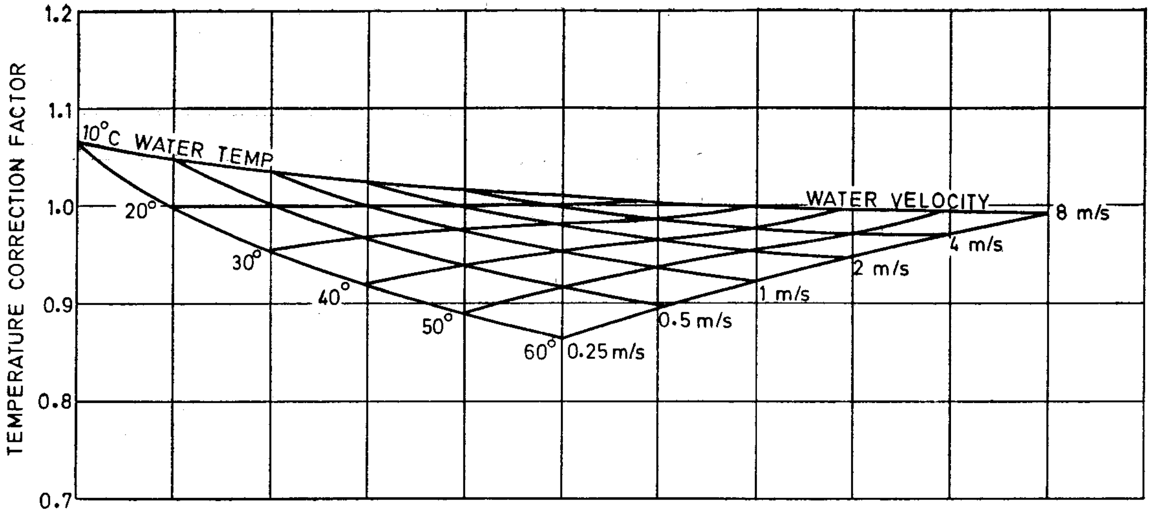


Fig. 7 Temperature Correction Factor for Loss in New Steel Pipes

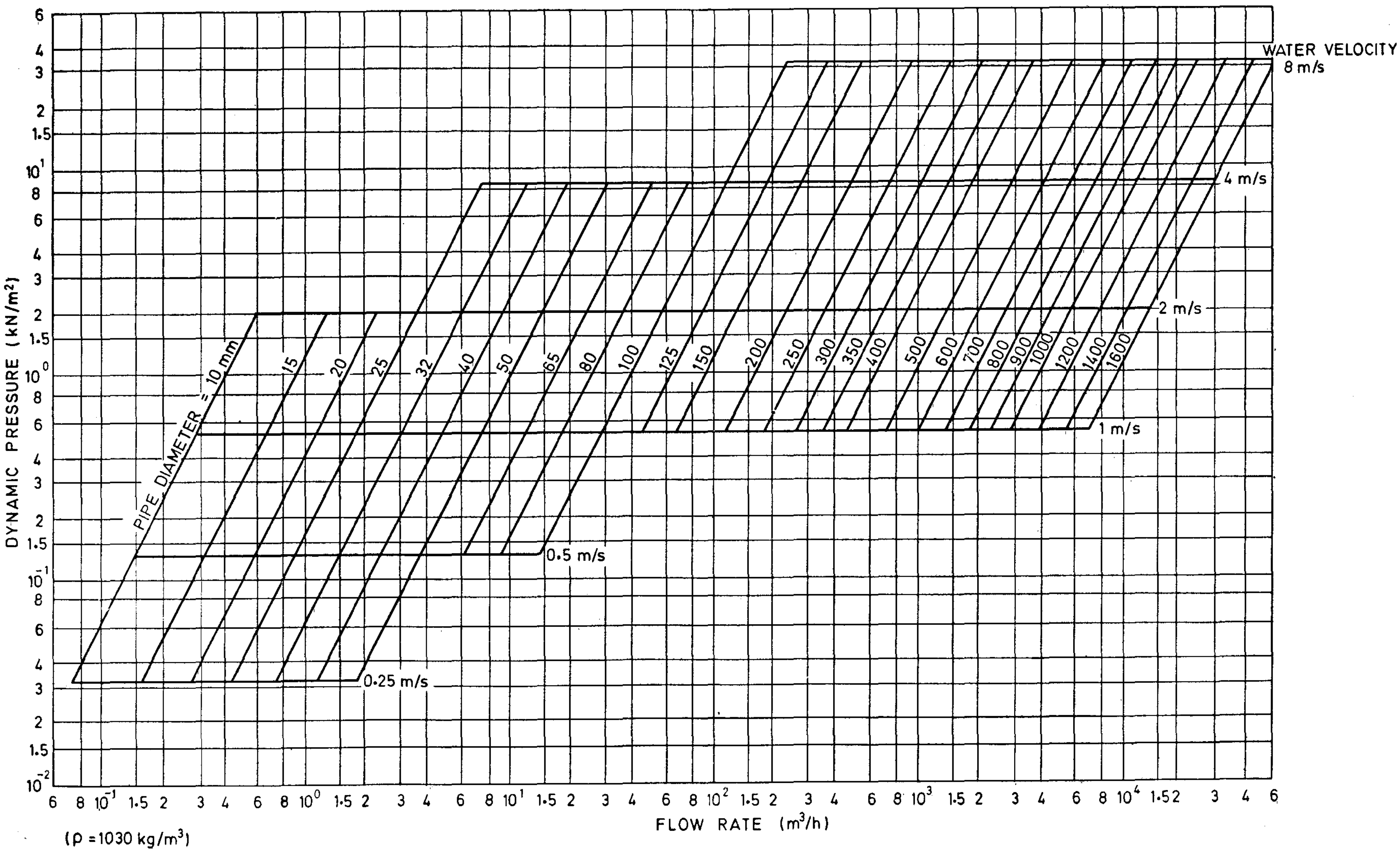


FIG. 8 DYNAMIC PRESSURE OF SALT WATER

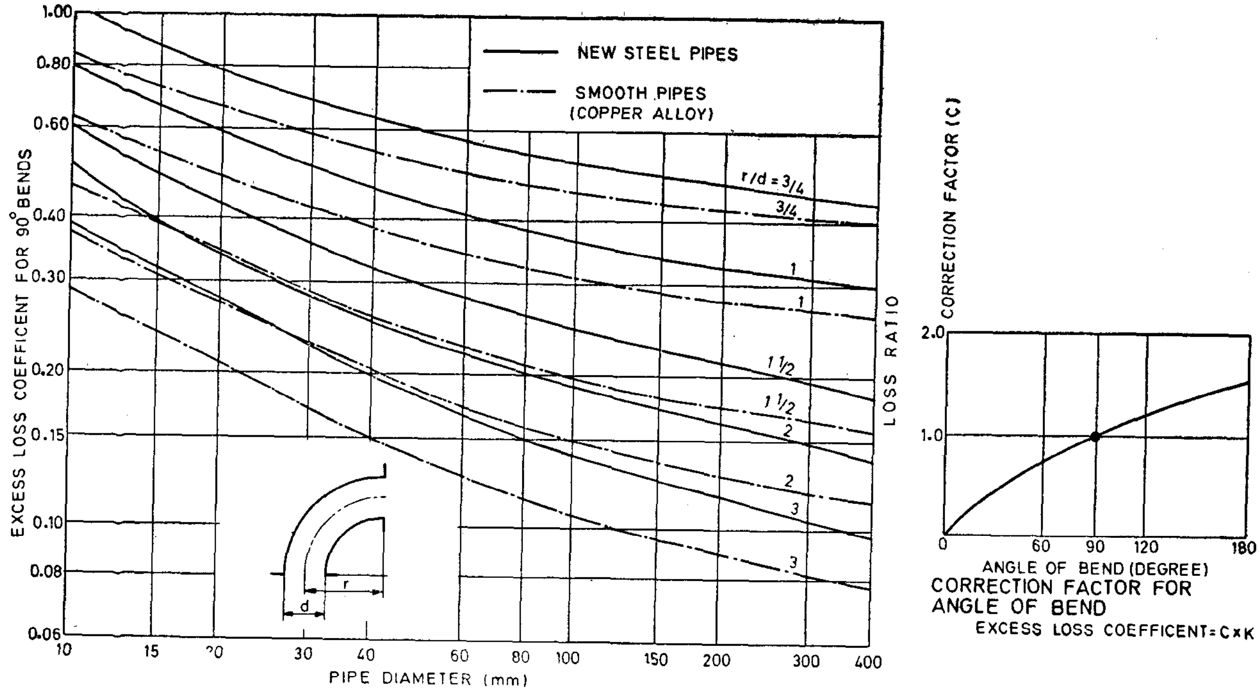


FIG. 9 EXCESS LOSS COEFFICIENTS FOR BENDS

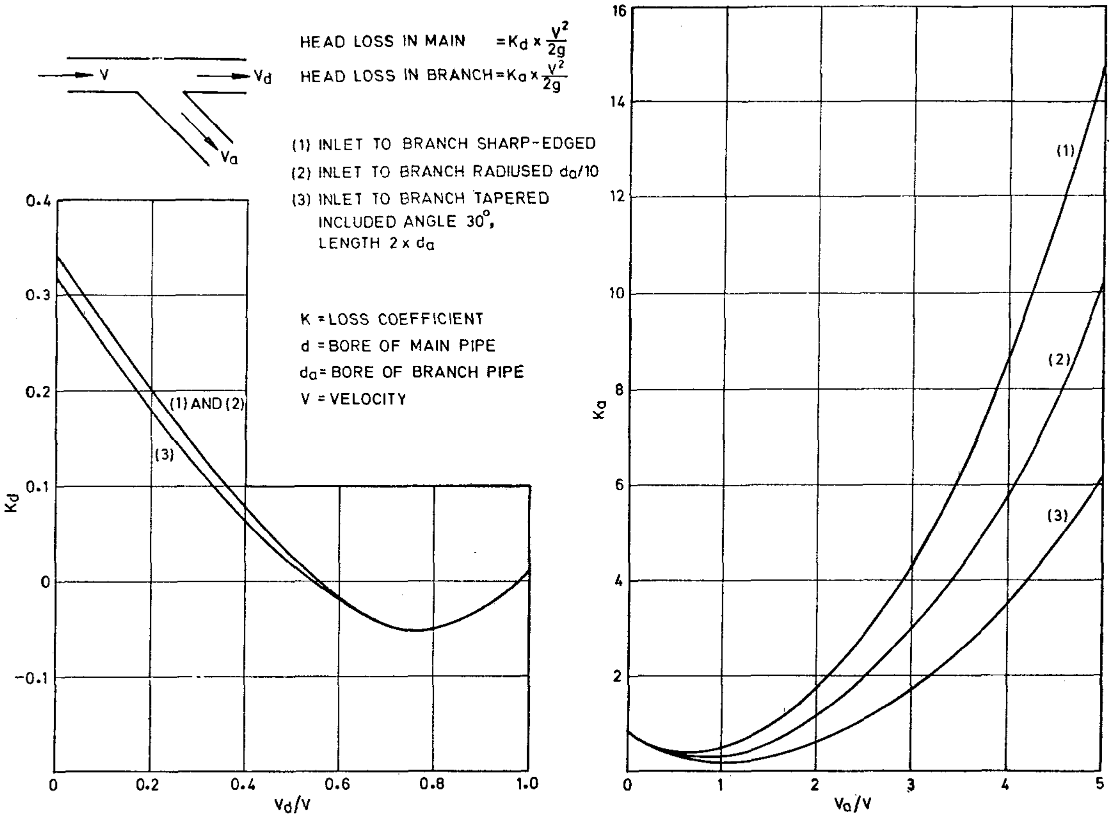


FIG. 10 LOSS COEFFICIENT FOR FLOW IN A 45° BRANCH (DIVIDING FLOW $0.352 \leqslant da/d \leqslant 1.00$)

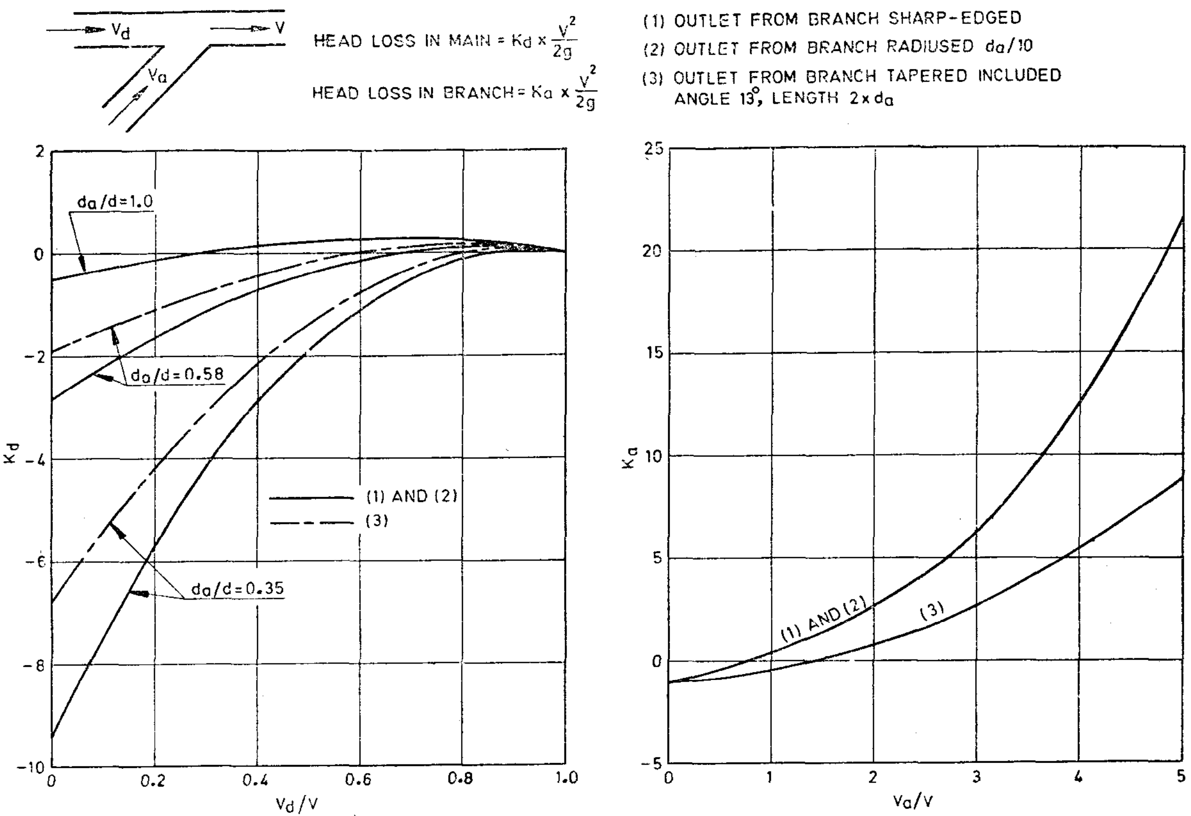


FIG. 11 LOSS COEFFICIENT FOR FLOW IN A 45° BRANCH (UNITING FLOW 0·352 ⩽ da/d ⩽ 1 00)

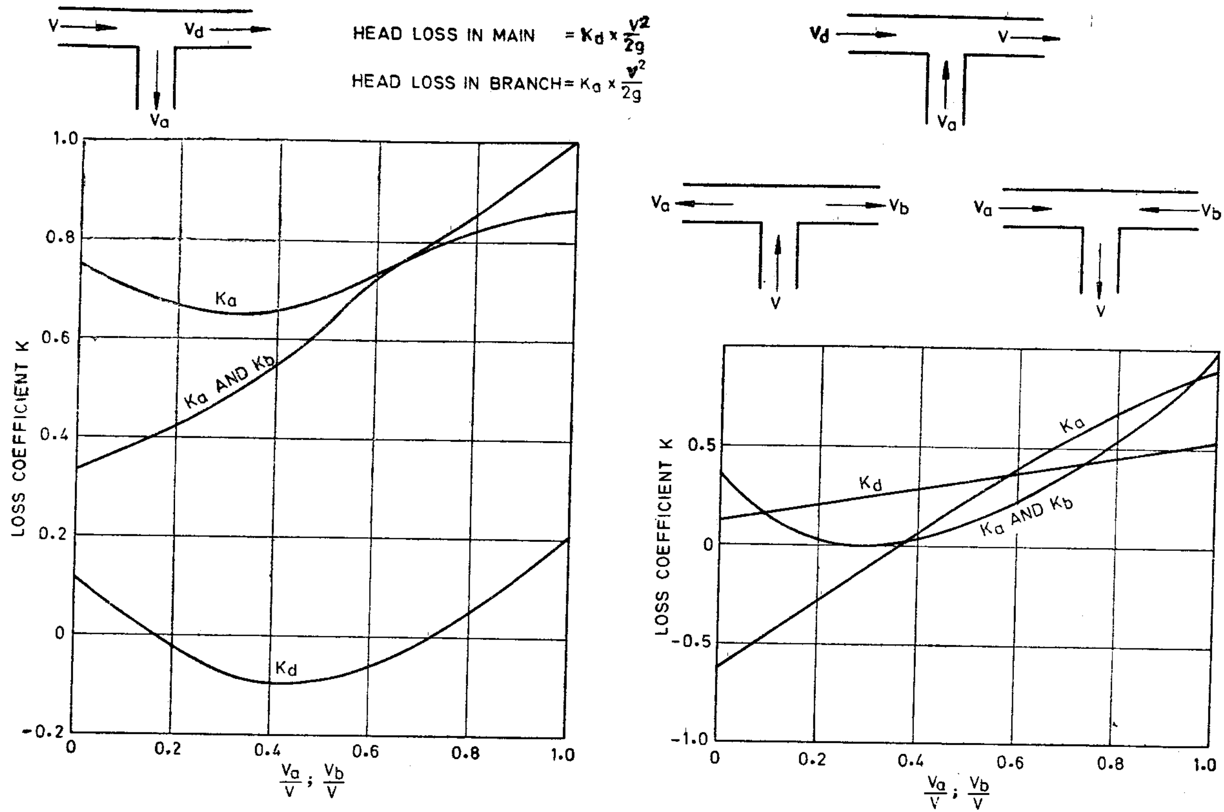


FIG. 12 LOSS COEFFICIENT FOR FLOW IN EQUI-DIAMETER RIGHT-ANGLE BRANCHES

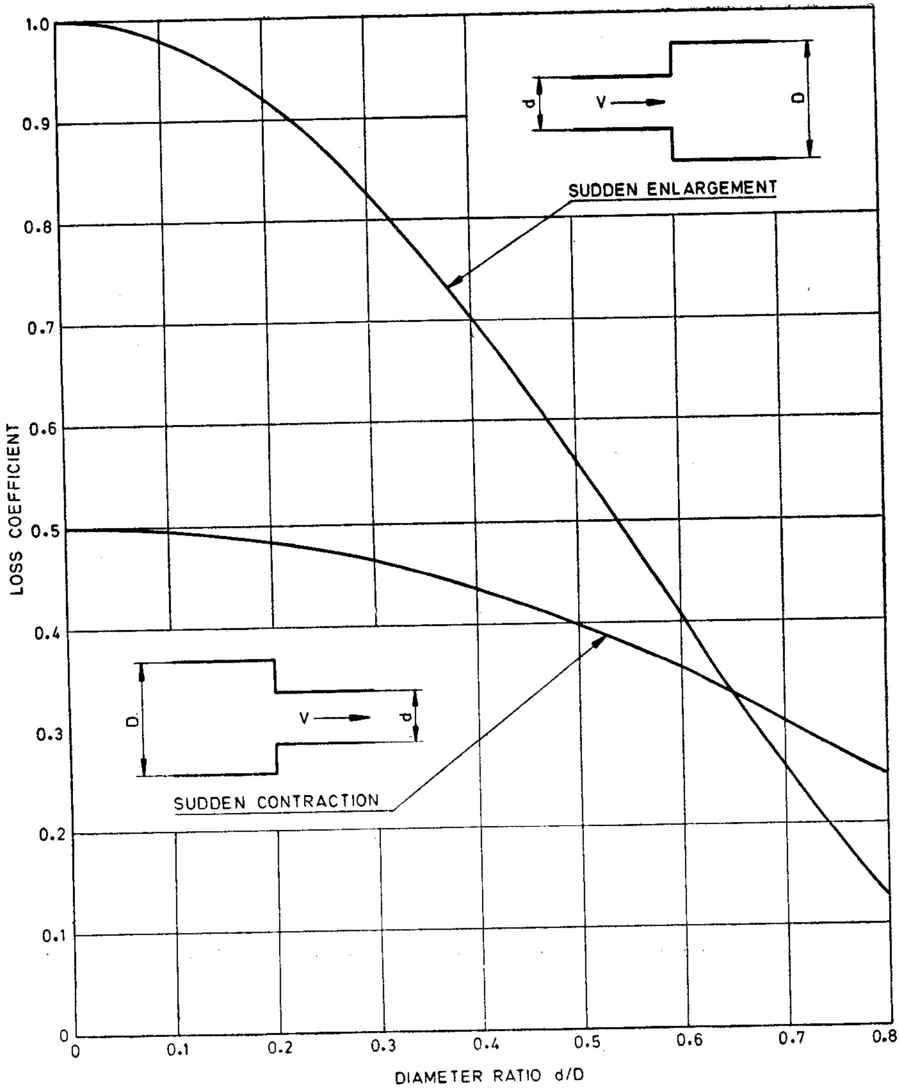
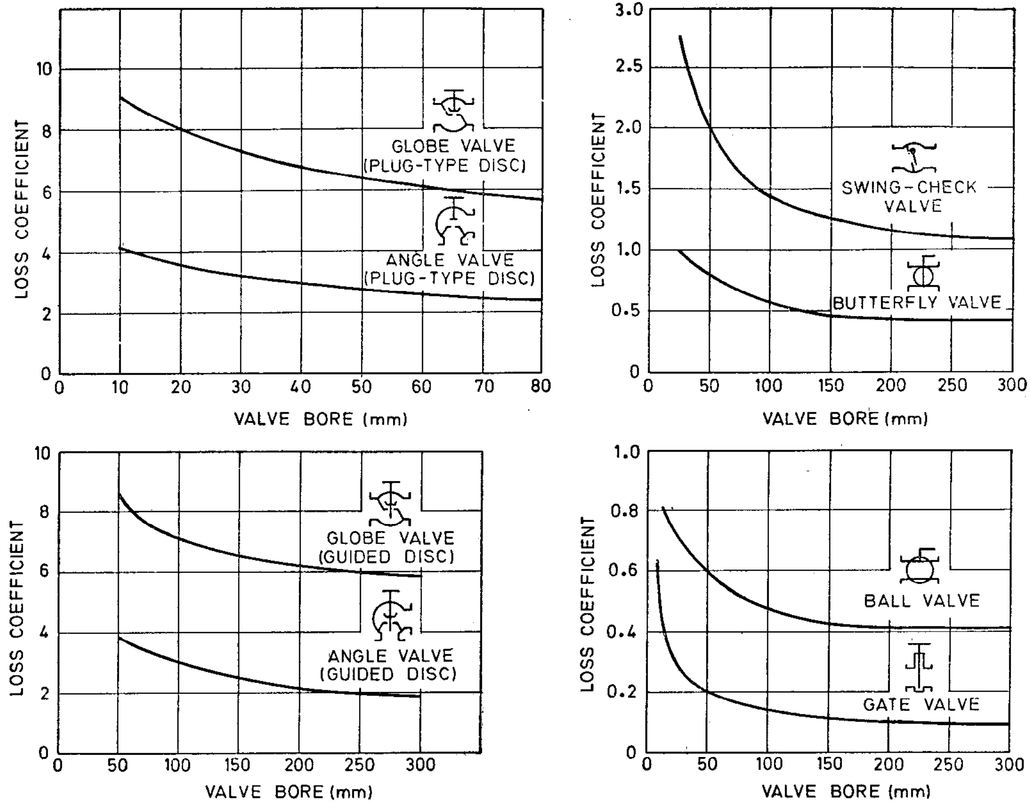


FIG. 13 LOSS COEFFICIENT FOR SUDDEN ENLARGEMENT AND CONTRACTION



NOTE — Drawings of valves are diagrammatic and not intended for use as symbols on diagrams.

FIG. 14 LOSS COEFFICIENTS FOR VALVES

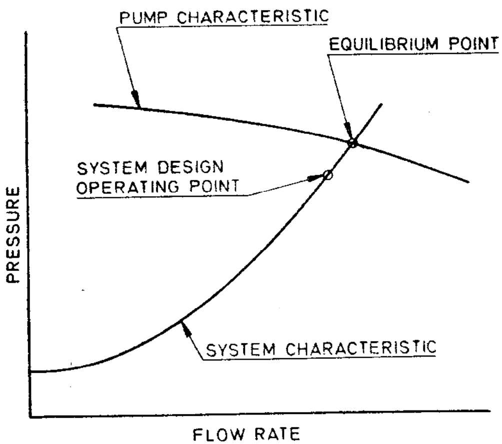


FIG. 15 COMPARISON OF PUMP AND SYSTEM CHARACTERISTICS

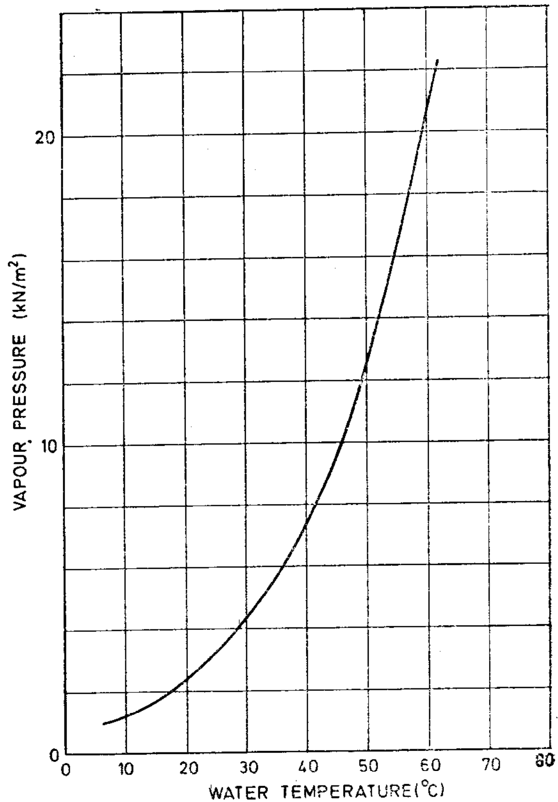


FIG. 16 VAPOUR PRESSURE OF WATER

APPENDIX C

(*Clause* 6.1)

MEASURES TO MINIMIZE CORROSION IN SALT WATER SYSTEMS

C-1. GENERAL

C-1.1 When components of a system are exposed to a corrosive environment it is necessary to consider the possibility that corrosion will occur, and, if so, the rate at which it will proceed. With materials of relatively low corrosion resistance, such as mild steel or galvanized steel exposed to sea water, corrosion will occur and it is necessary to consider only the effect of various factors on the rate of attack. For example, increasing the velocity of the water flow increases corrosion rates of these materials. In the case of materials that can be passivated in aerated sea water by the formation of thin, protective, oxide films in close contact with the metal surface, the possibility of attack can vary considerably. It is very low with some of the more resistant copper alloy, but under conditions of high velocity and turbulence tends to increase to some extent. When the normally resistant materials do break down, attack is usually localized and the rate of penetration may be comparatively high.

C-1.2 For most of the materials used in salt water systems, it is desirable to avoid high water velocities and turbulence; hence it is recommended to use smooth bends of reasonably large radius, to avoid sharp changes in direction or in pipe section, and to avoid protuberances. Such measures will help reduce rates of attack on materials of low resistance and will also reduce the possibility of attack on material of inherently high resistance, though with these latter there is a considerable margin of safety.

C-2. PROTECTIVE FILM FORMATION

C-2.1 Several copper alloys form good, self-healing protective films in salt water and those most used in salt water systems are aluminium brass and the cupro-nickels. The requisite amount of iron is an essential ingredient of the cupro-nickel alloys, if good corrosion resistance is to be obtained. Although it is not incorporated in the alloy, iron is also important in the case of aluminium brass, since good protective films on aluminium brass are always found to contain a significant proportion of iron oxides. This iron is normally derived from the corrosion of ferrous materials in the system, but it is possible to augment the effect by making a deliberate addition of soluble iron salt to the water.

C-2.2 A suitable procedure would be to introduce a strong solution of a cheap iron salt, such as ferrous sulphate, into the system by gravity or through a suitable metering pump. Good results are obtained by intermittent additions for, say, one hour per day, during which a concentration of one part per million of iron in the water is maintained (for example, 5 g of ferrous sulphate per cubic metre of water). After an initial period (say, for a few weeks), occasional treatments should suffice to keep protective films in good repair. If the iron salt is introduced in the vicinity of the cooling water, water intake beneficial results can be expected to spread to all copper alloy components throughout, the system, for example, not only to pipelines, but also to pumps, valves, heat exchanger tubes, etc.

C-2.3 Other recommended precautions are to prevent, as far as possible, the entry of debris into the system, and to avoid leaving stagnant salt water lying in the system for protracted periods. Protective films formed in service may by liable to break down under stagnant conditions, particularly in contact with polluted harbour or estuarine waters. The ferrous sulphate treatment mentioned above is therefore likely to be of most benefit if applied for a period before entering harbour, and again for a period after leaving.

C-2.4 In the commissioning of new systems it has been found beneficial to introduce ferrous sulphate or sodium di-methyl di-thio carbamate which assists in the formation of protective films.

C-3. DISSIMILAR METALS IN CONTACT

C-3.1 Currents flowing due to potential differences between dissimilar metals in contact with sea water (*see* Table 3 for guidance) can cause accelerated corrosion of the less noble metal (anode) and protection of the more noble metal (cathode) in the electrolytic or galvanic cell formed. The magnitude of the current flow, which determines the rate of attack of the anode, depends on many factors including the nature of the films and deposits formed on the electrodes (polarization effects), the composition of the sea water, its temperature and rate of flow, etc, as well as on the open circuit potential difference between the two metals. The relative areas of the two electrodes is also important in determining the intensity of attack on the anode.

C-3.2 A mixture of copper alloys with bare or galvanized steel in a salt water system would be likely to lead to significant acceleration of attack of the ferrous components near the points of contact. Apart from direct galvanice ffects, increased attack on ferrous materials can occur due to local cells set up when minute amounts of copper picked up in the water from copper alloy components deposit out on the iron or zinc surfaces.

Use of bare or galvanized steel downstream of copper alloy components should therefore be avoided. Indeed it is preferable to avoid this combination of materials altogether, if possible. Where the combination is unavoidable, it may be useful to fit between the two components an easily accessible and replaceable straight length of steel pipe of length at least one foot or three times the tube diameter (whichever is the greater). This 'corrosion piece' will require renewing relatively frequently; nevertheless there may be some overall advantage if accelerated attack on more vital or less easily replaced components is prevented.

Provision of sacrificial zinc or aluminium anodes in the sea-inlet boxes is also a practice to avoid galvanic corrosion if dissimilar metals are in contact in the sea water system.

C-3.3 Cast iron is in a similar category to mild steel but has better resistance to corrosion in sea water, and furthermore cast iron components are usually of relatively thick section. There is much practical experience of the satisfactory use of cast iron components such as valves and pump bodies in contact with copper alloy pipelines in sea water systems. Corrosion pieces could be used as a precautionary measure if desired.

C-3.4 The relatively small differences in potential between different copper alloy rarely lead to any difficulties in sea water systems.

C-4. ELECTRICAL LEAKAGE CURRENTS

C-4.1 Electrical leakage currents may flow in sea water piping systems, and if there is any interruption to a continuous metallic path, such as a high resistance joint, corrosion will occur where the current leaves the metal and passes into the water (particularly with direct current). Good electrical bonding throughout the sea water system is therefore desirable and this is usually obtained without taking any special steps. Brass or copper bonding strips may be fitted, for example, across the peripheries of flanged joints of similar metals.

TABLE 3 GALVANIC SERIES IN SEA WATER

(*Clause* C-3.1)

Noble (cathodic)

Graphite

Titanium

18 chromium/8 nickel stainless steel (passive)

' Monel ' metal

FV 520
18 chromium/2 nickel stainless steel
' Inconel '

70/30 cupro-nickel
Nickel-aluminium-bronze
Aluminium-silicon-bronze
90/10 cupro-nickel
Gunmetal
Phosphor-bronze

Copper
Rolled naval brass
Aluminium brass

High tensile brass

Tin
Lead
Lead/tin packing, solders, etc

Cast irons
18 chromium/8 nickel stainless steel (active)
Carbon steel

Aluminium

Zinc

Magnesium

Base (anodic)

For all practical purposes alloys included in brackets are equipotential and may be used together without special precautions.